ANDERSON & BUBLITZ

Influence of Temperature upon the Strength of Concrete

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INFLUENCE OF TEMPERATURE
UPON THE
STRENGTH OF CONCRETE

BY

J. ALBERT ANDERSON
AND
WALTER JOHN BUBLITZ

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

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COLLEGE OF ENGINEERING

May 25, 1914.

I hereby recommend that the thesis prepared under my direction by J. ALBERT ANDERSON and WALTER JOHN BUBLITZ entitled INFLUENCE OF TEMPERATURE UPON THE STRENGTH OF CONCRETE be accepted as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

A. B. McDaniel
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Recommendation concurred in:

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INFLUENCE OF TEMPERATURE ON THE STRENGTH OF CONCRETE.

I. INTRODUCTION.

1. PRELIMINARY.

A large number of concrete structures are built during the late fall and early spring when the temperatures are low and usually varied. Very little information exists regarding the effect of variations of temperature upon the setting action of concrete. Such information would be of the greatest value to contractors, for with it the time can be determined when the concrete will have gained sufficient strength to warrant the removal of the forms. Many of the concrete failures of the past have been attributed to the existing temperature conditions and the lack of knowledge due to them.

This thesis has been prepared for the purpose of furnishing some information of the relationship existing between the temperature, and the age and strength of concrete.

2. SCOPE OF INVESTIGATION.

It was first planned to mold a series of concrete specimens which could be stored in available places at different ranges of temperature and then tested at different ages in a standard compression testing machine to determine the effect of age and temperature upon the strength of concrete. After the first series of specimens were made, a failure of a reinforced concrete building occurred at Cedar Rapids, Iowa. This building had been in process of construction for six weeks and it was believed as a result of field investigations that its failure was due to cold weather conditions. Hence it was deemed desirable to test a second series of

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specimens, for the purpose of securing data which might throw some light upon the cause of the above failure.

II. PROCEDURE IN TESTING.

3. MATERIALS.

Cement. All the concrete used in the tests was made with Universal portland cement. The cement was taken from bags in the laboratory of the Engineering Experiment Station and stored in a covered metal can in the Road Laboratory. A sample was taken from the storage can and tested for normal plasticity, fineness, soundness and tensile strength. The results of the test to determine normal plasticity are given in Table 13, page 29, and indicate 23% water as the proper amount. Sieve analysis showed 16% retained on a No. 200 sieve and 2.9% retained on a No.100 sieve. See Table 14, page 29. Pats were made at the time of molding the briquettes and were ~~examined after being~~ stored one day in the moist closet; and then half were stored in air and half in water for 28 days. They showed no signs of cracks, discoloration or distortion. Sixteen briquettes were made and stored for one day in the moist closet, and then were placed in water. Eight briquettes were broken at the age of seven days and eight at the age of twenty-eight days. The average result for each test exceeded the minimum requirements of the Standard Specifications of the American Soceity for Testing Materials

Sand. The sand used came from a deposit of glacial drift near the Wabash river at Attica, Indiana. Nearly all of the clay, loam and other impurities had been removed by washing at the pit. A covered box in the Road Laboratory was used for the storage of the sand. A sample was tested for fineness. The results of this test

are given in Table 15, page 30 ; and are shown graphically in Fig. 1, page 18.

Stone. The crushed limestone came from Kankakee, Illinois. This material had been screened through a 1-inch screen and over a ¼-inch screen at the crusher plant. A sample was taken from the supply stored in a covered box in the Road Laboratory and tested for mechanical analysis. The results of this test are given in Table 16, page 31 and are graphically represented in Fig. 2, page 19.

Concrete. All the concrete was composed of 1 part cement, 2 parts sand, and 4 parts broken stone; and was proportioned by loose volume. The three constituent materials were weighed separately so that the total amount would be slightly in excess of that required for one specimen.

The mixing was done with a steel trowel and in a large galvanized iron pan. The cement and sand were first mixed dry to a uniform color and spread out in a layer of uniform thickness over the bottom of the pan. The stone was then added, and the whole mass given four complete turnings to secure thorough incorporation of the dry materials. Water was added, and the material turned until thoroughly mixed. The concrete was gathered together in a compact mass in one end of the mixing pan so as to reduce evaporation losses to a minimum. The time of mixing for each specimen was kept as nearly constant as possible. Tables 18, 20, 22, 28, 29, and 31 on pages 33, 34, 35, 40, 41, and 43 respectively, give the total weight of dry materials, and the temperatures of the water and of the air in the room at the mixing table.

4. TEST SPECIMENS.

Molding. All the specimens of the first series, hereafter

referred to as Sets A, B and C, were molded in the storage rooms, while those of the second series, hereafter referred to as Sets D, E and F, were molded in the Road Laboratory and moved to their respective storage rooms after a set of six hours.

The concrete was tamped by hand into the molds in layers about one and one-half inches in depth. The time of molding of each specimen was recorded and an effort made to keep this as nearly constant as possible for each type of specimen. After each specimen was molded, the weight of the residue in the mixing pan was determined and deducted from the total weight of the materials used, to ascertain the net weight. Values of the time of molding, weight of residue, and net weight for each specimen are given in Tables 18, 20, 22, 28, 29 and 31 on pages 33,34, 35,40,41 and 43 respectively.

Forms. The forms used for the first series of specimens were made of galvanized sheet-steel bent into the shape of cylinders, 6 inches in diameter and 6 inches high. Two adjustable, circumscribing circular bands held each form together.

The second series of specimens were molded in cube forms which were composed of two 6-inch channels,held 6 inches apart by means of four steel plates spaced 6 inches apart, making three forms for a 6-inch cube in each mold.

Storage. The first series of specimens comprised forty-five cylinders, 6 inches in diameter and 6 inches in height. This series was divided into three sets of fifteen specimens each, designated as Set A, Set B, and Set C. Set A was stored in the ice-storage room of the plant of the Smith Ice Company in Urbana, at an average temperature of 30° F. Set B was stored in the meat storage room of the plant of the Smith Ice Company in Urbana, at an average

temperature of 48.5° F. Set C was stored in the Cement Laboratory at an average temperature of 72.8° F.

The second series of specimens comprised fifty-one 6-inch cubes. This series was divided into three sets, Set D with fifteen specimens, Set E with eighteen specimens, and Set F with eighteen specimens. Set D was stored in the Cement Laboratory at an average temperature of 68° F. Set E was stored in the ice chest of the Dairy Department of the University at an average temperature of 35.5° F. Set F was stored in the ice-storage room of the plant of the Twin City Ice Company, at an average temperature of 27.1° F.

The above temperatures represent the averages of the readings of maximum and minimum thermometers for each day of storage. See Tables 19, 21, 23, 27, 30, and 32, on pages 33, 34, 35, 39, 42 and 44 respectively.

All the specimens while in storage were covered with several layers of moist sacking, which was kept in a uniformly damp condition. Every precaution was taken to keep the moisture content of the specimens uniform.

<u>Testing.</u> All the specimens of the first series, Sets A, B and C, were taken from their respective storage places to the Theoretical and Applied Mechanics Laboratory one day before they were tested. They were weighed, their bearing surfaces coated with plaster of paris, and then were stored in the open air of the laboratory for about twenty hours under an average temperature of about 75° F.

All the specimens of the second series, Sets D, E and F, were tested in about one hour from the time of their removal from the storage rooms. Two specimens of Set F, designated F 17 and F 18, after being stored under an average mean daily temperature of

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27.1° F. for forty-four days, were stored in the testing laboratory under an average daily temperature of about 70°F. for seven and twenty-one days, respectively, in order to gain sufficient strength to permit testing.

All the specimens were tested in compression in a Riehlé testing machine of 100,000 pounds capacity. The load was applied in each test through a ball and bearing socket head at a speed of 0.10 inch per minute.

In the first series, five specimens each of Sets A, B and C were tested at an age of seven days, five specimens of each set at an age of fourteen days and five specimens of each set at an age of twenty-eight days. The results of these tests are given in Tables 24, 25 and 26 on pages 36, 37 and 38 respectively.

In the second series, three specimens each of Sets D, E and F were tested at an age of four, seven, eleven, fourteen, twenty-eight and forty-four days, respectively; and one specimen of Set F at forty-four days, one at fifty-one days and one at sixty-five days. The results of these tests are given in Tables 33, 34, 35, 36, 37, and 38, on pages 45, 46 and 47 respectively.

III. DISCUSSION OF EXPERIMENTS ON CYLINDERS.

5. EXPLANATION OF DIAGRAMS.

The individual unit ultimate strengths in pounds per square inch as given in Tables 24, 25, and 26, on pages 36,37 and 38 together with their average values, were plotted in Fig. 4, 5, and 6, on pages 21, 22 and 23 respectively.

To find a continuous curve representing for each set of experiments the relation between the crushing strength and the age,

the average strength was first determined for each of the three ages; and then it was assumed that the curve sought would have the form $y = ax + bx^2 + cx^3$, in which y is the average strength in pounds per square inch for each age, x the age in days, and a, b, and c are constants to be determined. The average strength for each age gives a value for y, and the age for each group gives a value for x; and therefore we have three equations with three unknown quantities. Solving these three equations for Set A, page 21, gives $a = +187.2$, $b = -9.74$ and $c = +0.174$. Substituting these values in the above equation gives the numerical equation stated on page 21, and represented by the — —— line.

By a similar process the corresponding equations were obtained for Sets B and C, as shown on pages 22 and 23 respectively.

The numerical values of the constants a, b, and c in the above equation for the three sets A, B, and C, are plotted as shown in Fig. 10 on page 27, and a continuous curve was sketched through each of the three groups of points.

6. EFFECT OF TEMPERATURE.

Tables 1 to 3 inclusive, on page 11, show the relationship between strength and temperature at the different ages. For example, Table 1 shows that if the strength at an age of seven days for a mean temperature of 72° be represented by 100% then the strength at 48° is 91.7% and the strength at 30° is 74.4%. Similarly for Tables 2 and 3. The average of these tables for the three ages of seven, fourteen and twenty-eight days is that the strength at 48° is 92.5%, and at 30° is 71.6%.

To determine the relation between temperature and age, we

proceeded as follows: From Fig. 4 on page 21 the increments for each successive day were read from the curve and tabulated opposite 30° in Table 11 on page 15. Similarly from Fig. 5, page 22, the increments for a mean temperature of 48.5° was determined, and by interpolation the corresponding increments for 48° were determined and written opposite 48 in Table 11, page 15, and similarly in Fig. 6 on page 23, the increments for 72.8° were determined and by interpolation from these the increments for 72° were found and these were written opposite 72° in Table 11 on page 15. Then by interpolation between the several results for 30° and those for 48°, the intermediate values for each of several ages and temperatures were determined, and similarly results were interpolated between 48° and 72°.

IV. DISCUSSION OF EXPERIMENTS ON CUBES.

7. EXPLANATION OF DIAGRAMS.

To find a continuous curve for Set D to represent the relation between the crushing strength and the age, the average strength was first determined for each of the five ages; and then it was assumed that the curve sought would have the form $y = ax + bx^2 + cx^3 + dx^4 + ex^5$, in which y is the average strength in pounds per square inch for each age, x the age in days, and a, b, c, d, and e are constants to be determined. The average strength of each group gives a value for y, and the age for each group gives a value of x; and therefore we have five equations with five unknown quantities. Solving these five equations for Set D, page 24 gives $a = +384.91608$, $b = -73.193729$, $c = +7.685873$, $d = -0.355945$, and $e = +0.005724$. Substituting these values in the above general equation gives the numerical equation stated on page 24, and represented by the — —–— line.

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By a similar process the corresponding equation for Set E was determined. Since there were six ages of testing in this set, the general equation took the form $y = ax + bx^2 + cx^3 + dx^4 + ex^5 + fx^6$ and the six constants, a, b, c, d, e, and f were determined as for Set D.

The results for Set F are plotted in Fig. 9, page 26. The average temperature for this set is 27.1° F., the minimum being 18° F. and the maximum 42° F. The details of the range of temperatures are shown by the curves at the top of page 26. The range was so great and so erratic that no satisfactory results can be obtained from this set of experiments. For example, the first seven days under an average temperature of about 29° deg., the concrete showed a nearly uniform gain in strength. The temperatures for the next four days fell several degrees, and a slight drop in strength showed in the eleven day test. The strength at the end of fourteen days shows a decided increase owing to the high temperatures of the twelfth, thirteenth and fourteenth days. In all probability a slight thaw started during these high temperatures, and when the low temperatures of the succeeding days again set in, freezing took place.

Fig. 9. shows the results of the tests of sixteen cubes. The two remaining cubes of the series, i.e., F 17 and F 18, were badly disintegrated when taken out of storage, and were also so soft as not to make it worth while to test them; and therefore they were allowed to remain in the open air in the Materials Testing Laboratory under a temperature of about 70 F. for seven and twenty-one days respectively, when they were tested. This experiment shows conclusively that low temperatures merely retard the setting

action of concrete, and that alternating high and low temperatures cause disintegration and crumbling.

No attempt was made to derive a mathematical relation between the age and strength for Set F because of the inconsistency of the results.

8. EFFECT OF TEMPERATURE.

Tables 4 to 10 inclusive on pages 12, 13 and 14 show relative strength for different temperatures at different ages. For example, Table 4, page 12 shows that if the strength at 68° be considered 100%, then the strength at 35.5° is 57.3% and that at 27° is 49.6%, and similarly for Tables 5, 6, 7 and 8. Tables 9 and 10 show the percentage of strength of the different results in comparison with the strength at seven and twenty-eight days respectively.

Table 12, pages 16 and 17, gives the daily increment in strength due to a variation in temperature and age. This table was deduced in a manner exactly similar to that described for Table 11 on page 15, except that in the case of Table 12 the interpolation is between 35° and 68°.

Table No. 1.

Relation of Strength and Temperature at 7 Days - Cylinders.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of C
C	72°	7	1200	100.0
B	48°	7	1101	91.7
A	30°	7	893	74.4

Table No. 2.

Relation of Strength and Temperature at 14 Days -Cylinders.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of C
C	72°	14	1658	100.0
B	48°	14	1544	93.2
A	30°	14	1192	71.9

Table No. 3.

Relation of Strength and Temperature at 28 Days -Cylinders.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of C
C	72°	28	2093	100.0
B	48°	28	1937	92.5
A	30°	28	1429	68.4

Table No.4.

Relation of Strength and Temperature at 4 Days - Cubes.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of D
D	68°	4	777	100.0
E	35.5°	4	445	57.3
F	27°	4	386	49.6

Table No. 5.

Relation of Strength and Temperature at 7 Days - Cubes.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of D
D	68°	7	985	100.0
E	35.5°	7	472	48.0
F	27°	7	563	57.2

Table No. 6.

Relation of Strength and Temperature at 11 Days - Cubes.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of D
D	68°	11	1322	100.0
E	35.5°	11	920	69.5
F	27°	11	505	38.2

Table No. 7.

Relation of Strength and Temperature of Cubes at 14 Days.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of D
D	68°	14	1545	100.0
E	35.5°	14	1103	71.5
F	27°	14	638	41.3

Table No. 8.

Relation of Strength and Temperature of Cubes at 28 Days.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of D
D	68°	28	1848	100.0
E	35.5°	28	1548	83.7
F	27°	28	440	43.8

Table No. 9.

Comparison of Strength and Temperature of Cubes.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of 7 Day same class
D	68°	4	777	79.0
D	68°	11	1322	134.5
D	68°	14	1545	157.0
D	68°	28	1848	187.5
E*	35.5°	4	445	94.5
E	35.5°	11	920	195.0
E	35.5°	14	1103	234.0
E	35.5°	28	1548	328.0
F	27°	4	386	68.5
F	27°	11	505	89.7
F	27°	14	638	113.5
F	27°	28	440	78.0
F	27°	42	423	75.3

* In all probability setting action was retarded first seven days, consequently high percentages of increase in this set.

Table No. 10.

Relation of Strength and Temperature - Comparison of all Ages.

Class	Mean Temp.	Age Days	Ult.Strength lbs./sq.in.	% of 28 day same class.
D	68°	4	777	42.2
D	68°	7	985	53.5
D	68°	11	1322	71.7
D	68°	14	1545	83.7
E	35.5°	4	445	28.7
E	35.5°	7	472	30.5
E	35.5°	11	920	59.4
E	35.5°	14	1103	73.5
F *	27°	4	386	88.0
F	27°	7	563	128.0
F	27°	11	505	114.7
F	27°	14	638	145.0

Specimens were 6-inch Cubes.

* Decrease in strength due to freezing and final thaw of specimens.

Table No. 11.

Daily Strength Increments based on Curve $y = ax + bx^2 + cx^3$.

Cylinders.

Temp. Deg. F	Age in Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14
30	190	160	130	120	110	100	85	75	60	50	30	30	30	20
32	198	162	133	121	112	102	89	77	63	51	32	32	32	23
34	206	164	136	122	114	104	93	80	66	52	34	34	34	27
36	214	166	139	123	116	106	97	83	69	53	36	36	36	30
38	222	169	143	124	119	109	101	86	73	54	39	39	39	32
40	230	171	147	126	121	111	105	89	77	56	41	41	41	34
42	236	174	151	127	124	114	108	92	81	57	44	44	44	36
44	244	176	154	128	126	116	112	95	84	58	46	46	46	39
46	252	178	157	129	128	118	116	98	87	59	48	48	48	42
48	260	180	160	130	130	120	120	100	90	60	50	50	50	45
50	264	182	162	134	131	120	120	100	90	62	51	50	50	45
52	268	184	165	138	132	120	120	100	90	64	52	50	50	45
54	272	185	167	142	133	120	120	100	90	66	53	50	50	45
56	275	187	170	145	134	120	120	100	90	67	54	50	50	45
58	277	189	172	147	134	120	120	100	90	69	54	50	50	45
60	280	190	175	150	135	120	120	100	90	70	55	50	50	45
62	283	191	177	153	136	120	120	100	90	71	56	50	50	45
64	285	193	180	155	136	120	120	100	90	73	56	50	50	45
66	288	195	182	158	137	120	120	100	90	74	57	50	50	45
68	292	196	185	162	138	120	120	100	90	76	58	50	50	45
70	296	198	187	166	139	120	120	100	90	78	59	50	50	45
72	300	200	190	170	140	120	120	100	90	80	60	50	50	45

Temp. Deg. F	Age in Days 15	16	17	18	19	20	21	22	23	24	25	26	27	28
30	20	20	20	20	20	20	20	20	20	20	10	10	10	10
32	23	22	21	21	21	21	21	21	21	21	12	12	12	12
34	27	24	22	22	22	22	22	22	22	22	14	14	14	14
36	30	26	23	23	23	23	23	23	23	23	16	16	16	16
38	32	29	24	24	24	24	24	24	24	24	19	19	19	19
40	34	31	26	26	26	26	26	26	26	26	21	21	21	21
42	36	34	27	27	27	27	27	27	27	27	24	24	24	24
44	39	36	28	28	28	28	28	28	28	28	26	26	26	26
46	42	38	29	29	29	29	29	29	29	29	28	28	28	28
48	45	40	30	30	30	30	30	30	30	30	30	30	30	30
50	45	40	30	30	30	30	30	30	30	30	30	30	30	30
52	45	40	30	30	30	30	30	30	30	30	30	30	30	30
54	45	40	30	30	30	30	30	30	30	30	30	30	30	30
56	45	40	30	30	30	30	30	30	30	30	30	30	30	30
58	45	40	30	30	30	30	30	30	30	30	30	30	30	30
60	45	40	30	30	30	30	30	30	30	30	30	30	30	30
62	45	40	30	30	30	30	30	30	30	30	30	30	30	30
64	45	40	30	30	30	30	30	30	30	30	30	30	30	30
66	45	40	30	30	30	30	30	30	30	30	30	30	30	30
68	45	40	30	30	30	30	30	30	30	30	30	30	30	30
70	45	40	30	30	30	30	30	30	30	30	30	30	30	30
72	45	40	30	30	30	30	30	30	30	30	30	30	30	30

Table No. 12.

Daily Strength Increments(lbs./sq.in.) - Cubes.

Curve $y=ax+bx^2+cx^3+dx^4+ex^5+fx^6$.

Temp. Deg.F	Age in Days. 1	2	3	4	5	6	7	8	9	10
35	140	110	95	95	80	75	70	70	65	65
36	144.5	112.5	96.7	96.2	79.8	75.3	70.3	70.3	65.6	65.6
38	153.6	117.6	100.0	98.6	79.5	75.6	70.9	70.9	66.5	66.5
40	162.7	122.7	103.4	101.0	79.3	75.9	71.5	71.5	67.4	67.4
42	171.8	127.8	106.7	103.4	78.9	76.2	72.1	72.1	68.3	68.3
44	180.9	132.9	110.1	105.8	78.6	76.5	72.7	72.7	69.2	69.2
46	190.0	138.0	113.4	108.2	78.3	76.8	73.3	73.3	70.1	70.1
48	199.1	143.1	116.8	110.6	78.0	77.1	73.9	73.9	71.0	71.0
50	208.2	148.2	120.1	113.0	77.7	77.4	74.5	74.5	71.9	71.9
52	217.3	153.3	123.5	115.4	77.4	77.7	75.1	75.1	72.8	72.8
54	226.4	158.4	126.8	117.8	77.1	78.0	75.7	75.7	73.7	73.7
56	235.5	163.5	130.2	120.2	76.8	76.3	76.3	76.3	74.6	74.6
58	244.6	168.6	133.5	122.6	76.5	78.6	76.9	76.9	75.5	75.5
60	253.7	173.7	137.9	125.0	76.2	78.9	77.5	77.5	76.4	76.4
62	262.8	178.8	141.2	127.4	75.9	79.2	78.1	78.1	77.3	77.3
64	271.9	183.9	144.6	129.8	75.6	79.5	78.7	78.7	78.2	78.2
66	281.0	189.0	147.9	132.2	75.3	79.8	79.3	79.3	79.1	79.1
68	290	195	150	135	75	80	80	80	80	80

Temp. Deg.F	Age in Days. 11	12	13	14	15	16	17	18	19	20
35	60	60	60	55	50	50	40	40	30	30
36	60.6	60.6	60.3	55.2	50	49.6	39.8	39.8	29.8	29.8
38	61.8	61.5	60.9	55.5	50	49.0	39.5	39.5	29.5	29.5
40	63.0	62.4	61.5	55.8	50	48.4	39.2	39.2	29.2	29.2
42	64.2	63.3	62.1	56.1	50	47.8	38.9	38.9	28.9	28.9
44	65.4	64.2	62.7	56.4	50	47.2	38.6	38.6	28.6	28.6
46	66.6	65.1	63.3	56.7	50	46.6	38.3	38.3	28.3	28.3
48	67.8	66.0	63.9	57.0	50	46.0	38.0	38.0	28.0	28.0
50	69.0	66.9	64.5	57.3	50	45.4	37.7	37.7	27.7	27.7
52	70.2	67.8	65.1	57.6	50	44.8	37.4	37.4	27.4	27.4
54	71.4	68.7	65.7	57.9	50	44.2	37.1	37.1	27.1	27.1
56	72.6	69.6	66.3	58.2	50	43.6	36.8	36.8	26.8	26.8
58	73.8	70.5	66.9	58.5	50	43.0	36.5	56.5	26.5	26.5
60	75.0	71.2	67.5	58.8	50	42.4	36.2	36.2	26.2	26.2
62	76.2	72.3	68.1	59.1	50	41.8	35.9	35.9	25.9	25.9
64	77.4	73.2	68.7	59.4	50	41.2	35.6	35.6	25.6	25.6
66	78.6	74.1	69.3	59.7	50	40.6	35.3	35.3	25.3	25.3
68	80	75	70	60	50	40	35	35	25	25

Table No. 12 (Continued)

Daily Strength Increments (lbs./sq.in.) - Cubes.

Temp. (Deg.F)	Age in Days. 21	22	23	24	25	26	27	28
35	30	30	25	25	25	25	25	20
36	29.6	29.6	24.6	24.6	24.4	24.4	24.2	19.4
38	29.0	29.0	24.0	24.0	23.5	23.5	23.0	18.5
40	28.4	28.4	23.4	23.4	22.6	22.6	21.8	17.6
42	27.8	27.8	22.8	22.8	21.7	21.7	20.6	16.7
44	27.2	27.2	22.2	22.2	20.8	20.8	19.4	15.8
46	26.6	26.6	21.1	21.1	19.9	19.9	18.2	14.9
48	26.0	26.0	21.0	21.0	19.0	19.0	17.0	14.0
50	25.4	25.4	20.4	20.4	18.1	18.1	15.8	13.1
52	24.8	24.8	19.8	19.8	17.2	17.2	14.6	12.2
54	24.2	24.2	19.2	19.2	16.3	16.3	13.4	11.3
56	23.6	23.6	18.6	18.6	15.4	15.4	12.2	10.4
58	23.0	23.0	18.0	18.0	14.5	14.5	11.0	9.5
60	22.4	22.4	17.4	17.4	13.6	13.6	9.8	8.6
62	21.8	21.8	16.8	16.8	12.7	12.7	8.6	7.7
64	21.2	21.2	16.2	16.2	11.8	11.8	7.4	6.8
66	20.6	20.6	15.6	15.6	10.9	10.9	6.2	5.9
68	20	20	15	15	10.	10	5.0	5

Mechanical Analysis of Sand

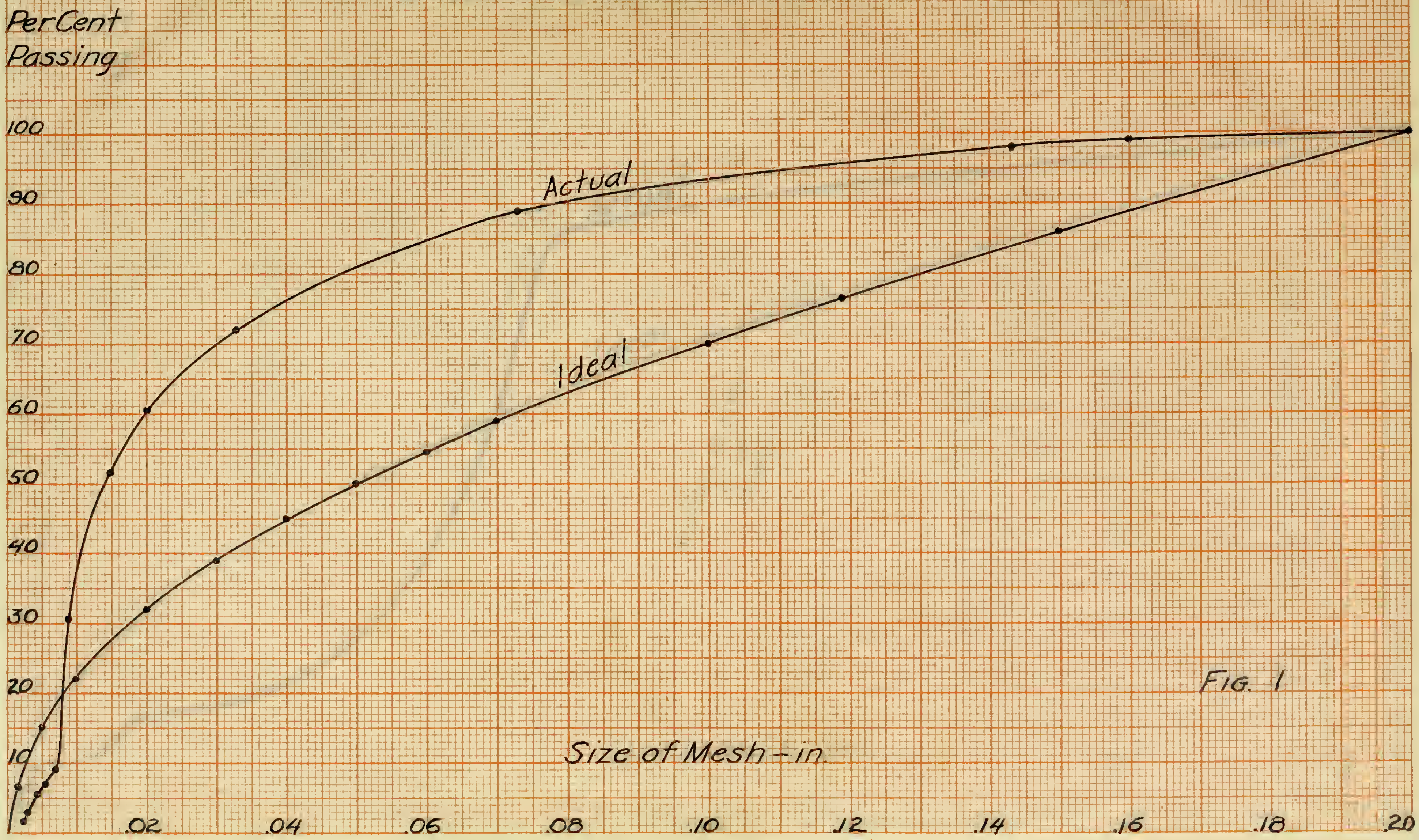


Fig. 1

EUGENE DIETZGEN CO. CHICAGO NEW YORK Nº 345


MECHANICAL ANALYSIS OF SAND
Per cent Passing
Size of Mesh
Fig 1

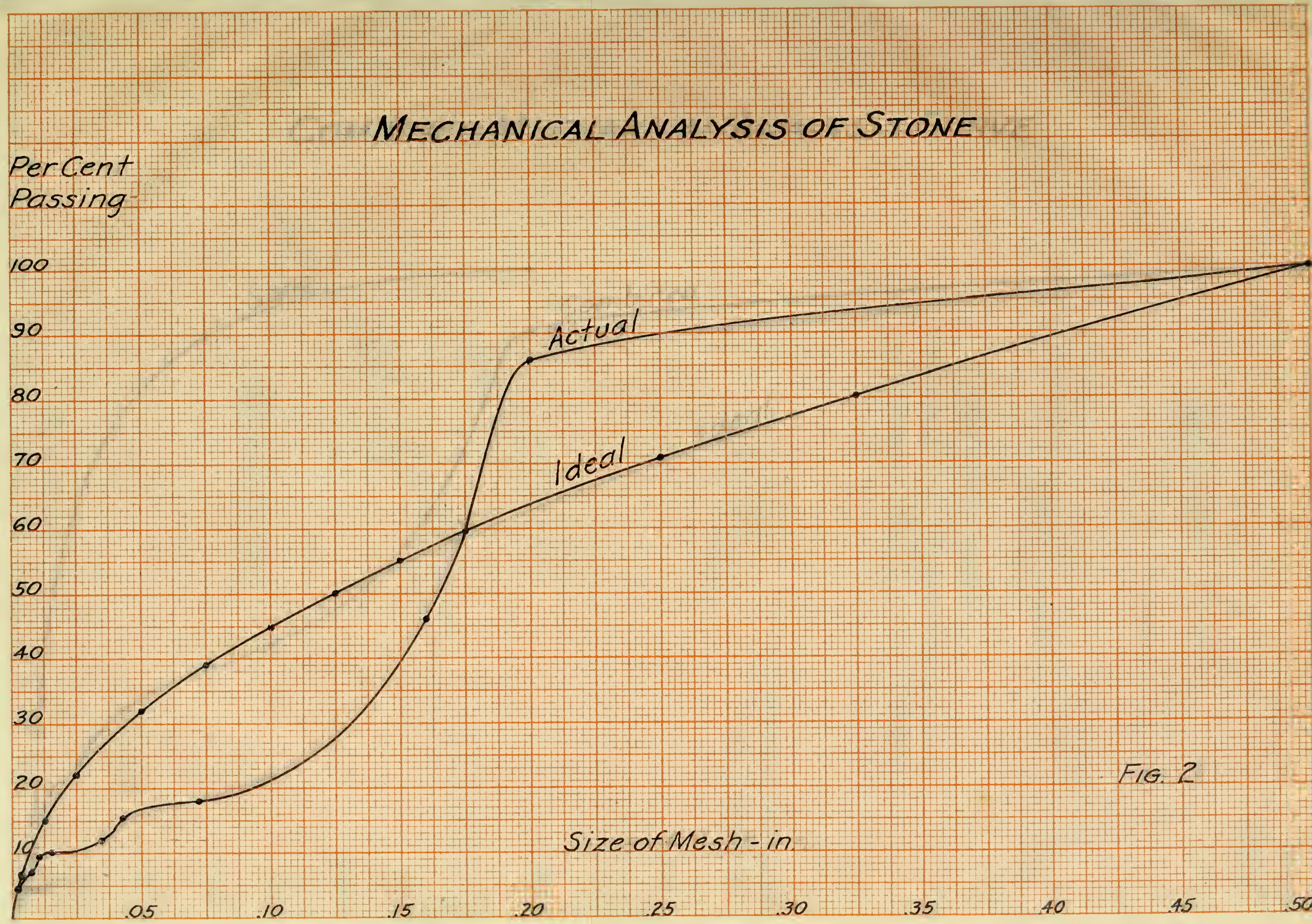
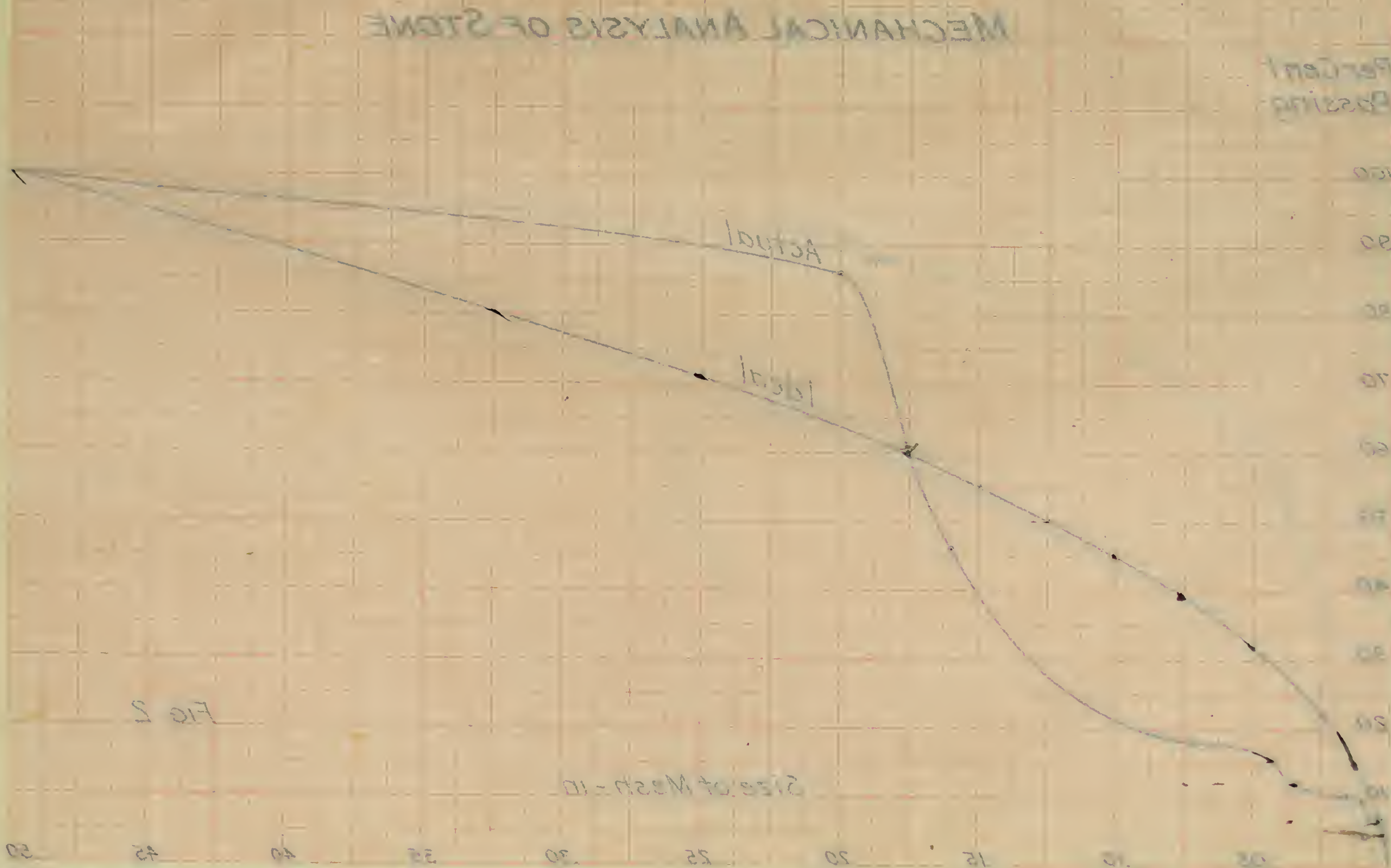
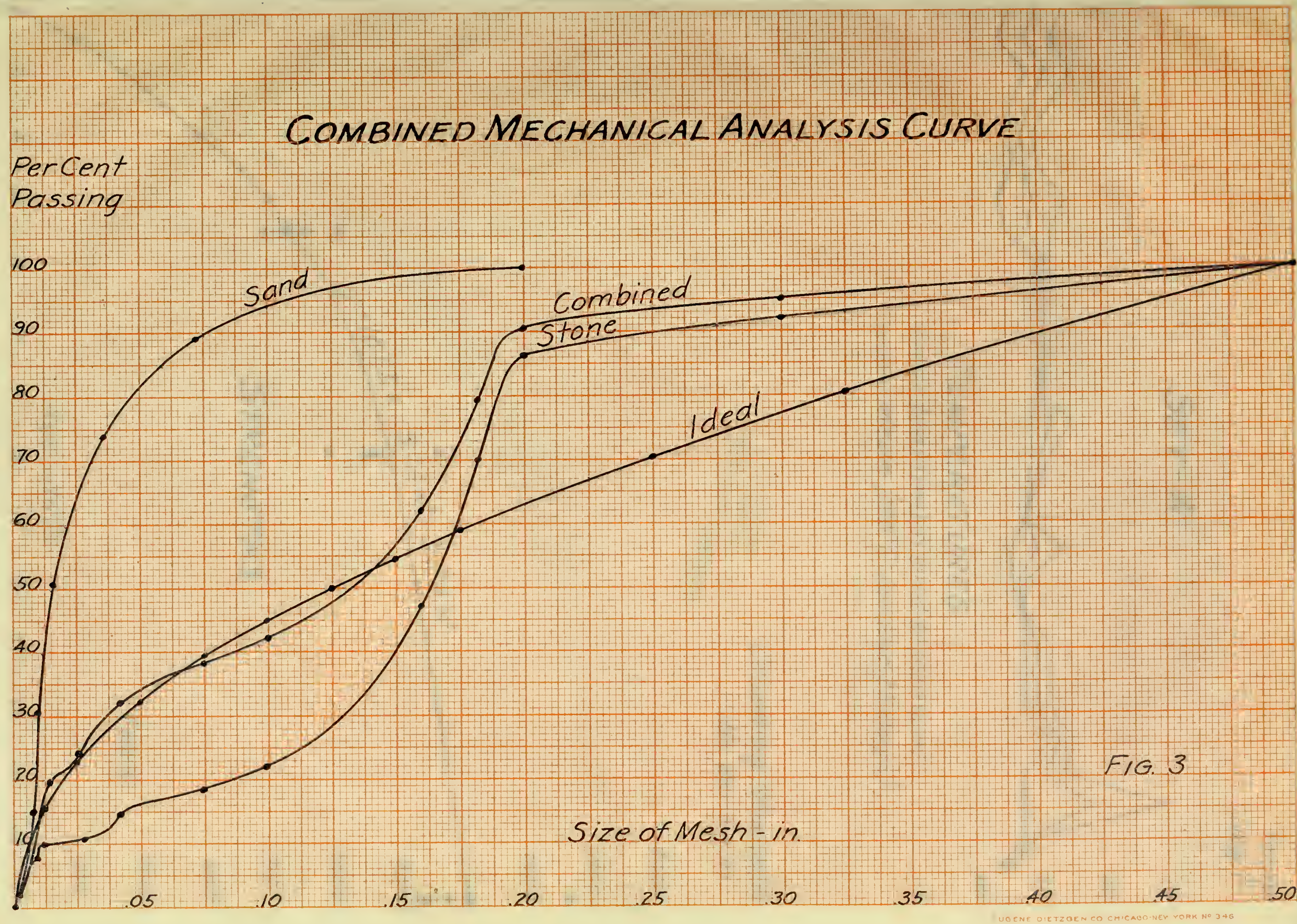
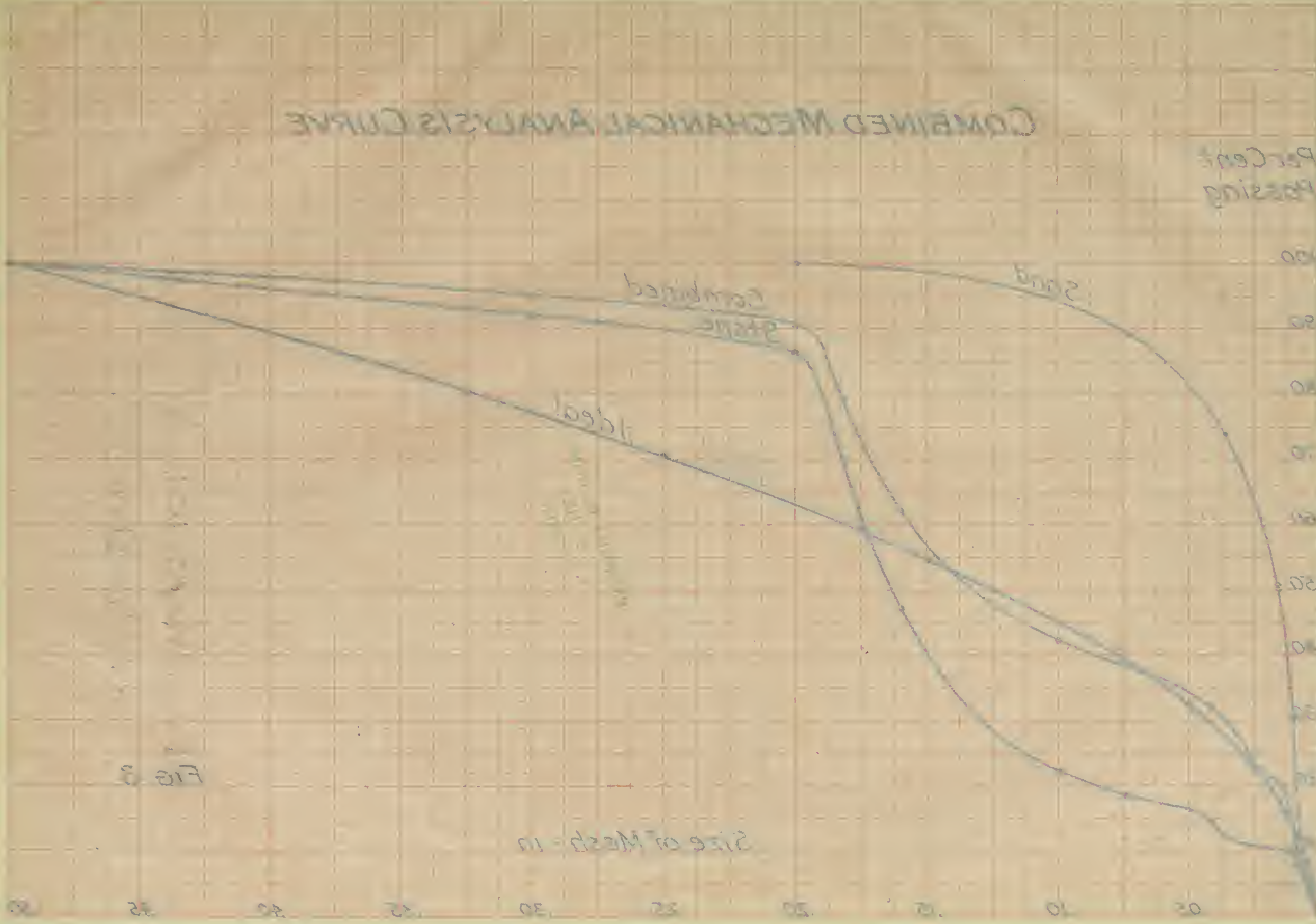


FIG. 2

EUGENE DIETZGEN CO CHICAGO-NEW YORK No 346


MECHANICAL ANALYSIS OF STONE
Per Cent Passing
Actual
Ideal
Fig 2
Size of Mesh - in
100
90
80
70
60
50
40
30
20
10
50
45
40
35
30
25
20
15
10
05


COMBINED MECHANICAL ANALYSIS CURVE
Per Cent Passing
100
90
80
70
60
50
40
30
20
10
Sand
Combined
Stone
Ideal
Size of Mesh - in.
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50
FIG. 3
UGENE DIETZGEN CO CHICAGO-NEW YORK Nº 346


Combined Mechanical Analysis Curve
Per Cent Passing
Sand
Combined
Stone
Ideal
Fig 3
Size of Mesh - in

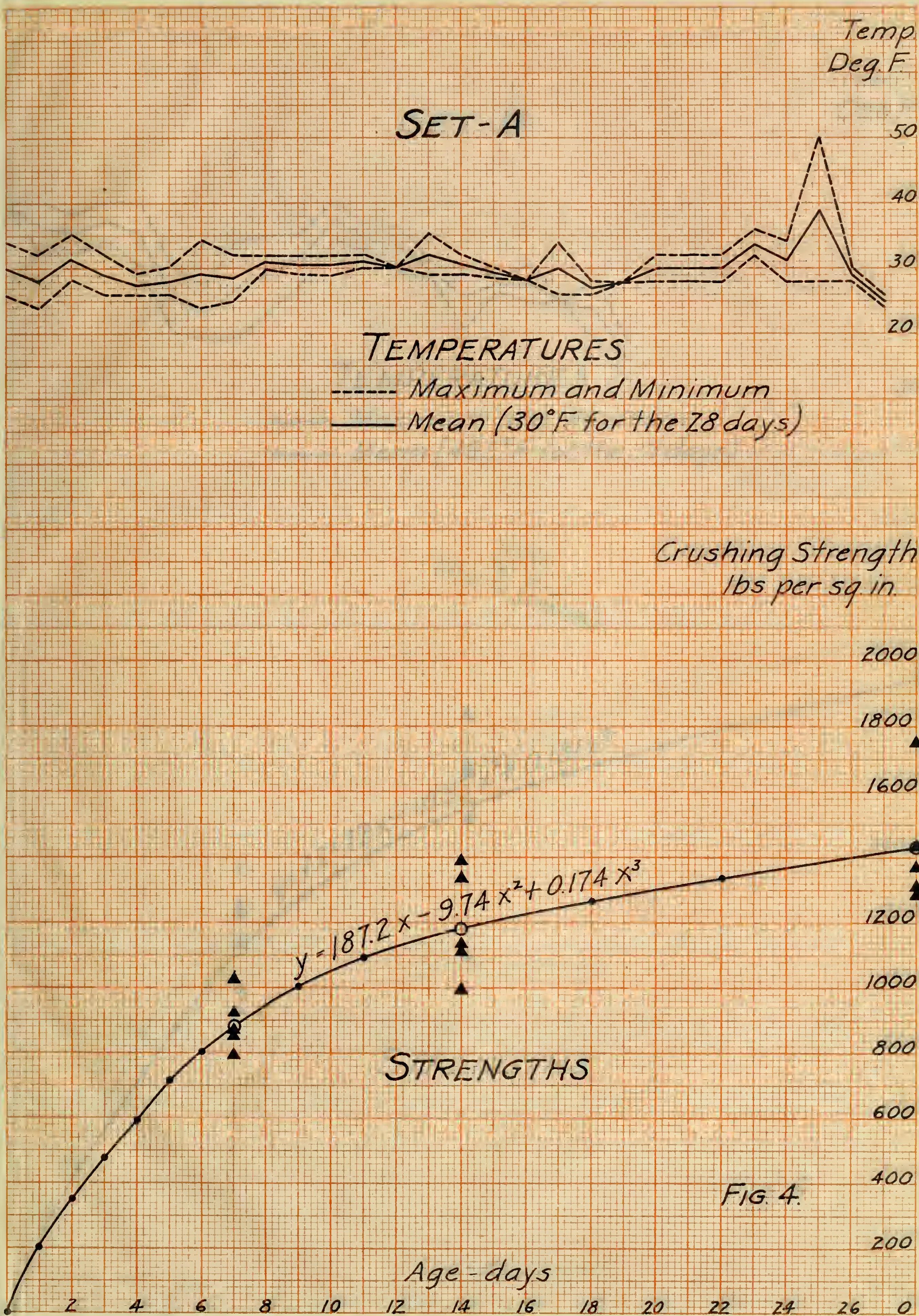

Temp.
Deg. F.
SET - A
50
40
30
20
TEMPERATURES
------ Maximum and Minimum
—— Mean (30°F for the 28 days)
Crushing Strength
lbs per sq. in.
2000
1800
1600
1200
1000
800
600
400
200
y = 187.2 x − 9.74 x² + 0.174 x³
STRENGTHS
Age - days
2
4
6
8
10
12
14
16
18
20
22
24
26
0

FIG. 4.

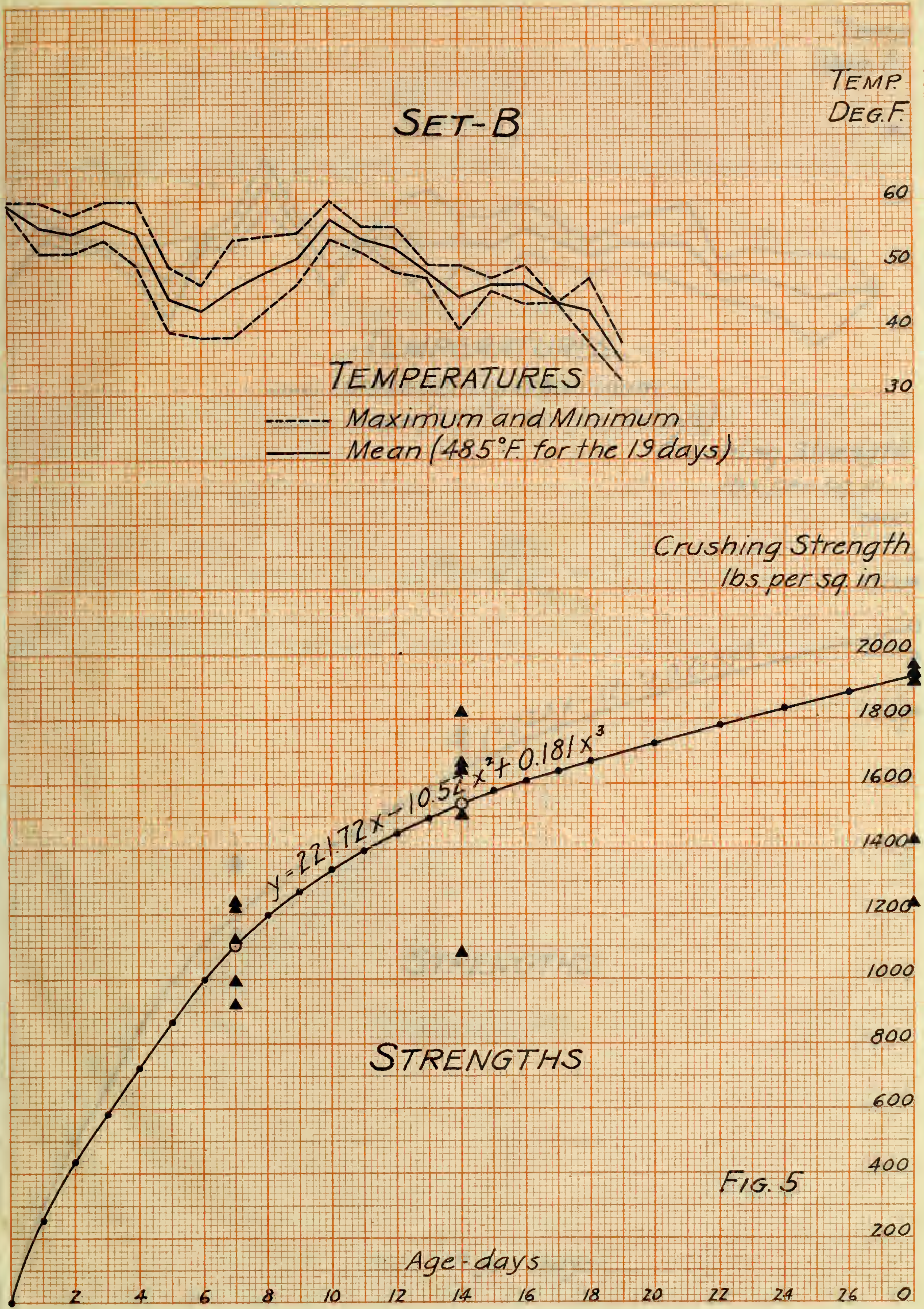


FIG. 5

EUGENE DIETZGEN CO. CHICAGO-NEW YORK Nº 346

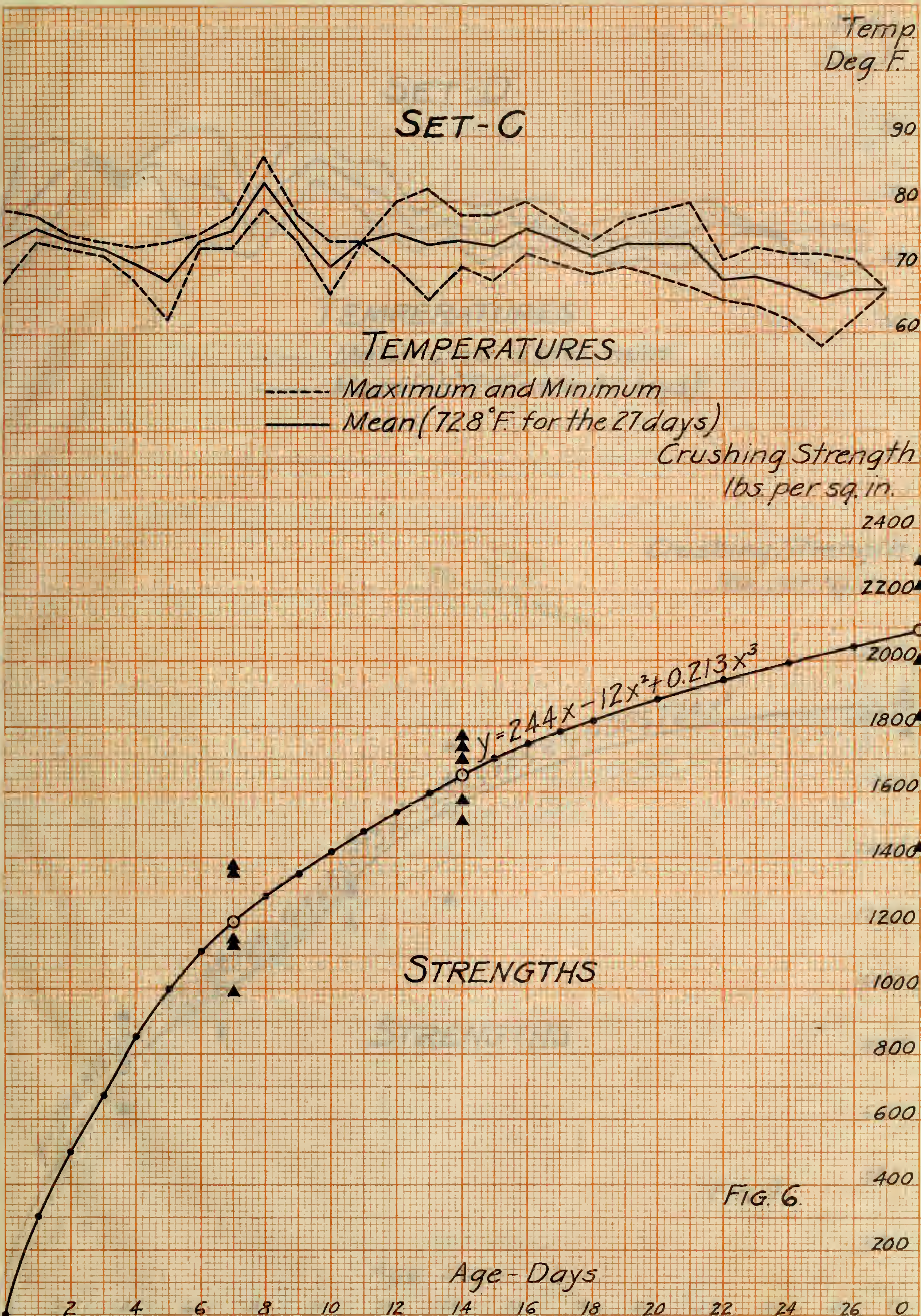
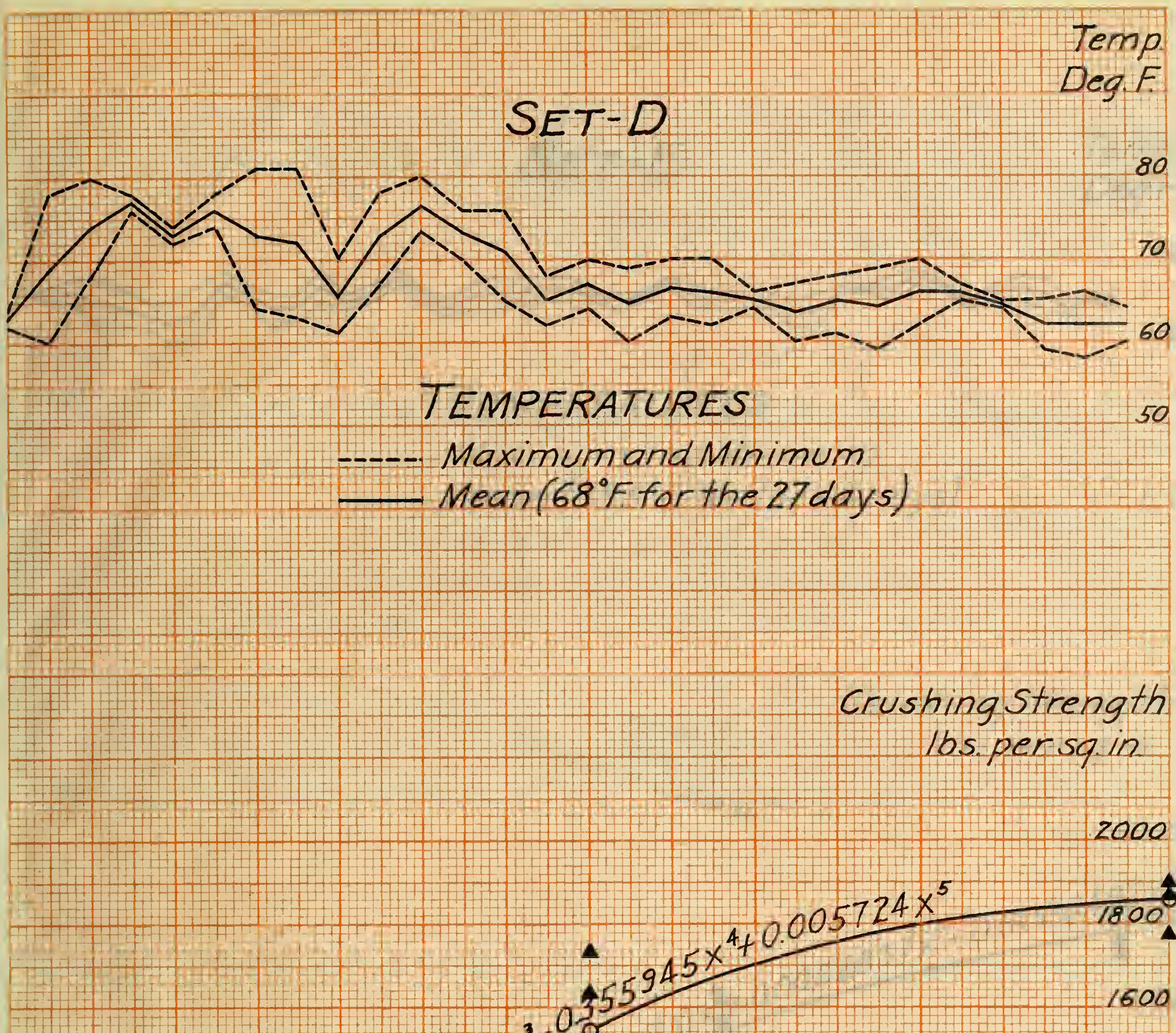


FIG. 6.

EUGENE DIETZGEN CO. CHICAGO NEW YORK No 346


SET-D
Temp. Deg. F.
80
70
60
50
TEMPERATURES
----- Maximum and Minimum
—— Mean (68°F for the 27 days)
Crushing Strength lbs. per sq. in.
2000
1800
1600
1400
1200
1000
800
600
400
200
0
y = 384.91608x − 73.193729x² + 7.685873x³ − 0.355945x⁴ + 0.005724x⁵
STRENGTHS
FIG. 7
Age - days
2
4
6
8
10
12
14
16
18
20
22
24
26

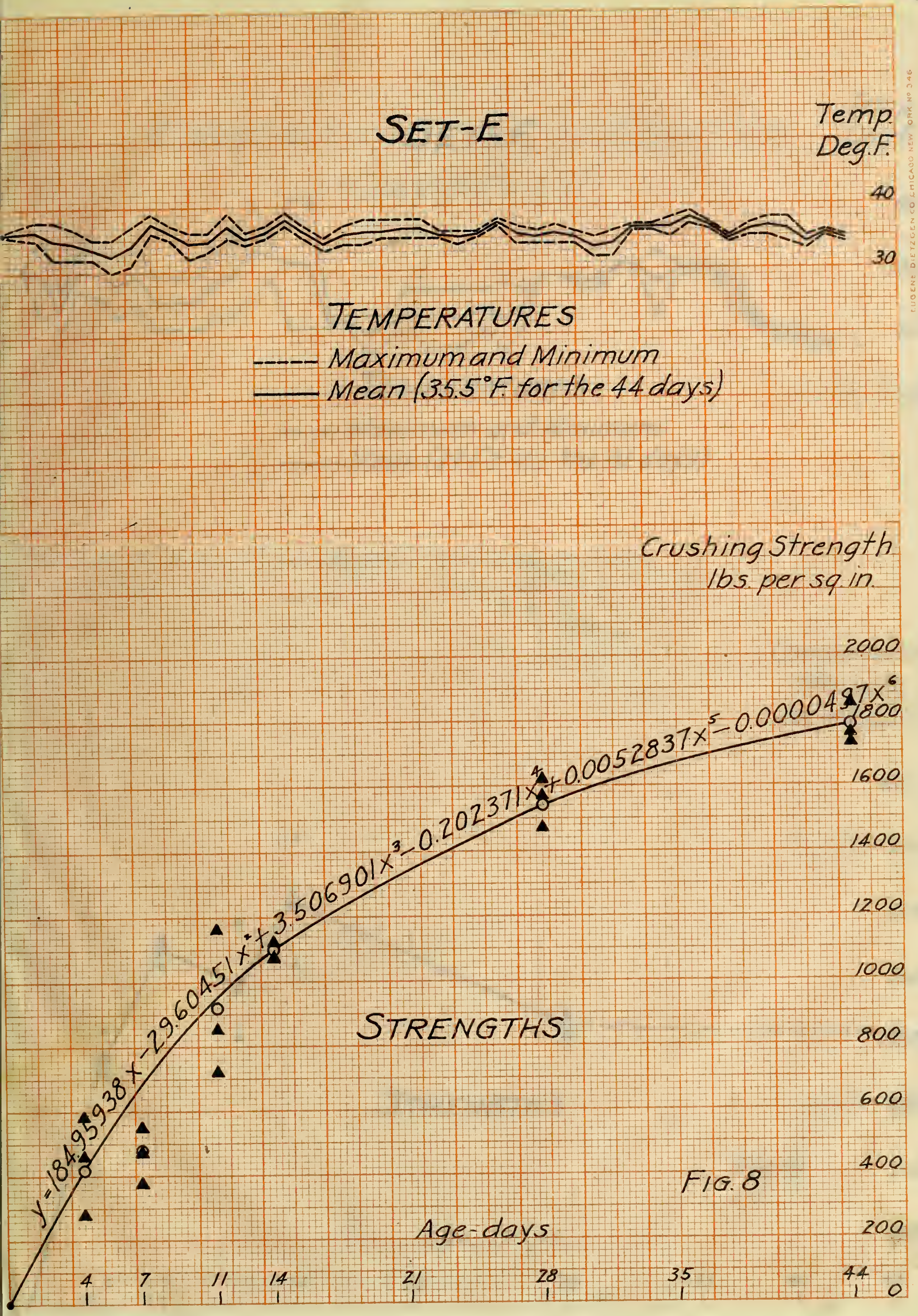
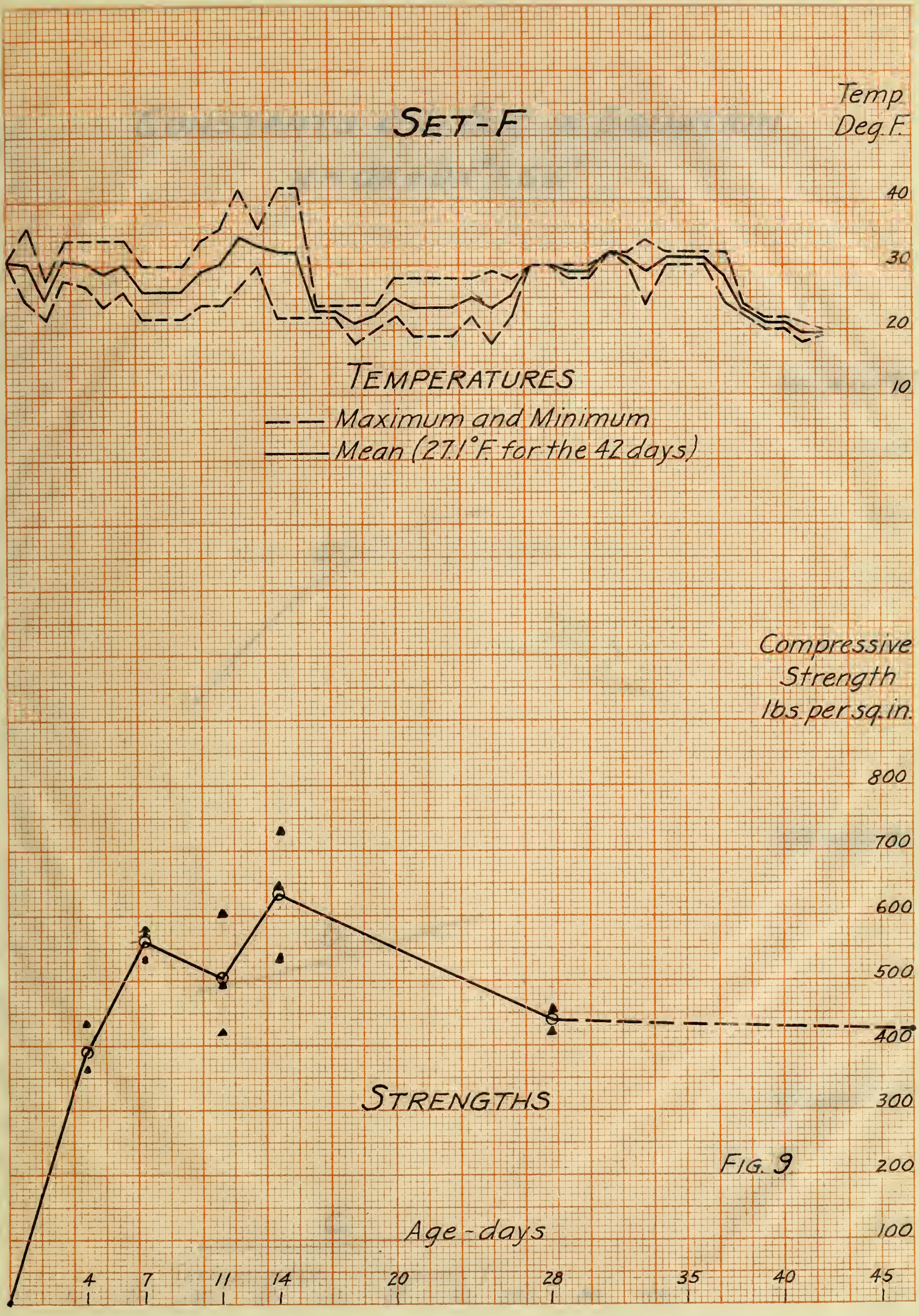


FIG. 8

EUGENE DIETZGEN CO. CHICAGO NEW YORK No 346


SET-F
Temp
Deg. F.
40
30
20
10
TEMPERATURES
— — Maximum and Minimum
—— Mean (27.1°F. for the 42 days)
Compressive
Strength
lbs. per sq. in.
800
700
600
500
400
300
200
100
STRENGTHS
FIG. 9
Age - days
4
7
11
14
20
28
35
40
45

Constants a, b, & c in Equation

$$y = ax + bx^2 + cx^3$$

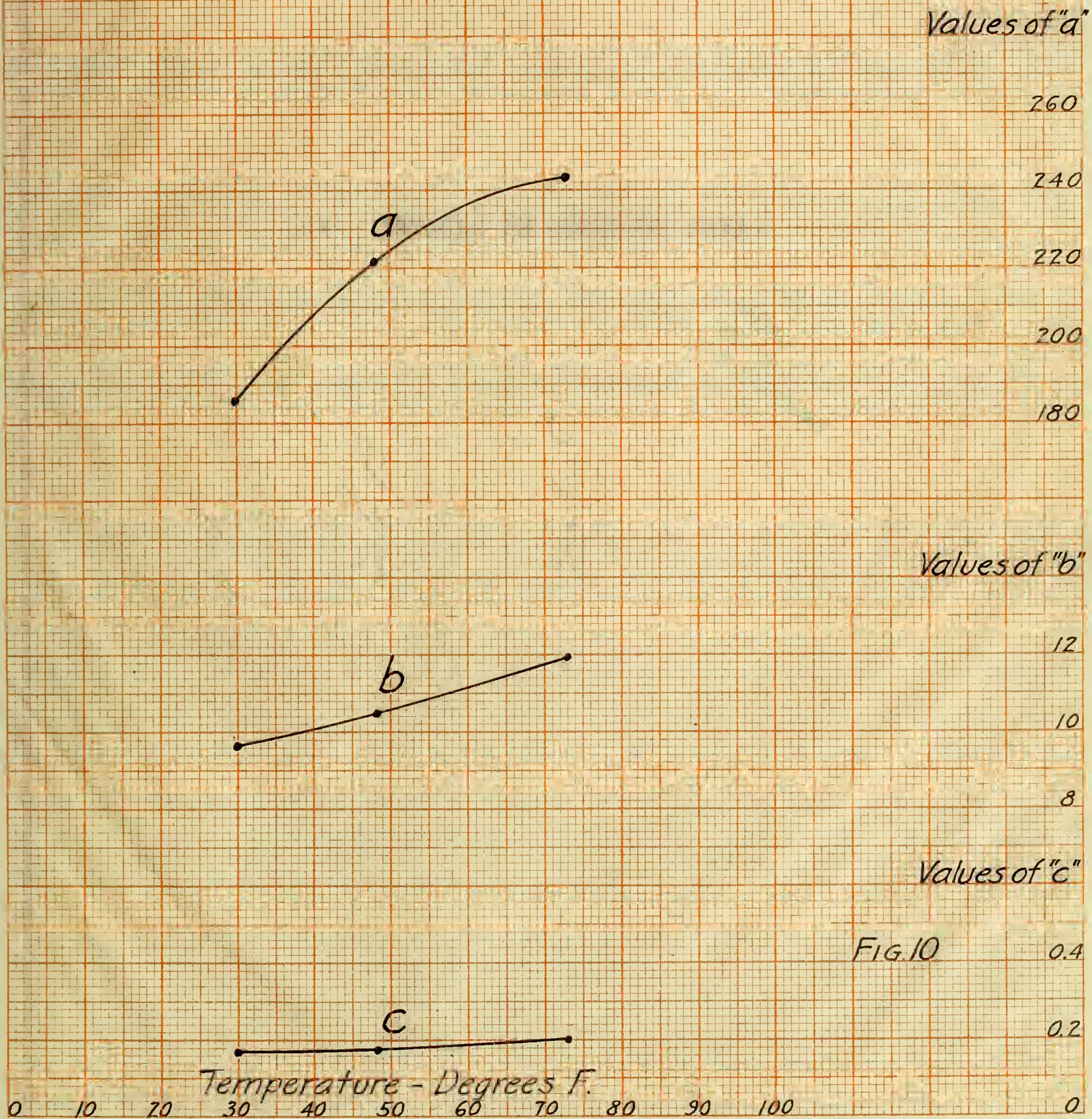


Fig. 10

UGENE DIETZGEN CO. CHICAGO-NEW YORK No 346

V. DETAILS OF OBSERVED DATA.

CEMENT TESTS.

Plasticity: by Penetration Method.

Table No. 13.

Trial No.	Gms. Cement	Percent H_2O	Penetration mm.	Time sec.
1	500	23.0	6.2	30
2	500	23.5	17.2	30
3	500	23.0	12.0	30
4	500	22.5	7.0	30

23% water gave best results.

Fineness: Sample of 1000 units used.

Table No. 14.

No. of Sieve	Units Retained	% retained on sieve.
200	160	16
100	29	2.9

TEST OF SAND:-

The sand used was placed in a dryer for thirty-six hours and then a sample of 1000 grams was placed upon a nest of standard sieves and sifted for forty minutes.

Results. Table No. 15.

No. of Sieve	Size of Mesh	Grams Retained	% Passing
¼	.20	4.4	99.99
5	.16	113.7	99.55
10	.073	150.1	88.18
20	.034	215.8	73.17
40	.015	212.5	51.59
60	.009	221.2	30.34
74	.0078	27.4	8.22
100	.0045	20.8	5.48
150	.0033	10.5	2.30
200	.0027	3.9	1.75
Passing 100		13.6	1.36
	Total =	999.9	

TEST OF STONE:-

The stone, like the sand, was placed upon the dryer for thirty-six hours and a sample of 2500 grams was placed upon a nest of standard sieves and sifted for forty minutes.

Results. Table No. 16.

No. of Sieve	Size of Mesh	Grams Retained	% Passing
1/2	0.5	323.0	99.99
1/4	0.20	1008.0	86.8
5	0.16	615.0	46.5
8	0.0955	100.6	22.1
10	0.073	58.0	18.5
16	0.042	105.4	15.75
20	0.034	15.0	11.5
30	0.022	21.1	10.95
40	0.015	10.5	10.1
60	0.009	67.0	9.7
74	0.0078	12.1	7.0
100	0.0045	19.8	6.52
150	0.0033	22.3	[illegible].73
200	0.0027	8.5	4.82
Passing 200		112.1	4.48
	Total =	998.4	

COMBINATION OF STONE AND SAND CURVES:-

The stone and sand curves were combined in order that the curve for aggregate might be compared with the ideal curve, a parabola. In combining the curves, 3500 grams (the combined weight of stone and sand) was used as 100% and the amounts of sand and stone passing the same sieve were added and the percentage passing calculated.

Table No. 17.

No. of Sieve	Size of Mesh	Amount of sand retained	Amount of stone ret'd	Total	% passing
$\frac{1}{2}$	.50		323.0	323	99.99
$\frac{1}{4}$	.20	4.4	1008.0	1012.4	91.2
5	.16	113.7	615.0	748.7	62.4
8	.0955		100.6	100.6	41.0
10	.073	150.1	58.0	208.1	38.1
16	.042		105.4	105.4	32.1
20	.034	215.8	15.0	230.8	29.1
30	.022		21.1	21.1	22.5
40	.015	212.5	10.5	222.5	21.9
60	.009	221.5	67.0	288.2	15.6
74	.0078	27.4	12.1	39.5	7.3
100	.0045	26.8	19.8	46.6	6.2
150	.0033	10.5	22.3	32.8	4.9
200	.0027	3.9	8.5	12.4	3.9
passing 200		13.6	112.1	125.7	3.6

From the combined curve it can be seen that there was an excess of large material. This is undoubtedly the cause of the visible voids which reduced the area and thereby weakened some of the specimens. No efforts were made to make the combined curve take the direction of the ideal as it was the authors' idea to make the investigation as practical as possible.

Table No. 18.

Moulding of Set A. Cylinders

Number Specimen	* Time Moulding Min.	Total Wgt. lbs.	Wgt. Residue lbs.	Net Wgt. lbs.	Temperature Air Deg.C	Temperature Water Deg.C.	Per cent Water
A 1		16.63	1.13	15.50	0°	21	10
A 2		"	1.60	15.03	"	"	"
A 3		"	1.29	15.34	"	"	"
A 4		"	0.98	15.65	"	"	"
A 5		"	1.39	15.24	"	"	"
A 6		"	1.54	15.09	"	16	"
A 7		"	1.21	15.42	"	21	"
A 8		"	0.97	15.66	"	"	"
A 9		"	1.40	15.23	"	"	"
A 10		"	1.50	15.13	"	"	"
A 11		"	0.95	15.68	"	21.5	"
A 12		"	1.32	15.31	"	"	"
A 13		"	1.24	15.39	"	"	"
A 14		"	1.81	14.82	"	"	"
A 15		"	1.16	15.47	-3.2°	20.2	"

* Time not taken.

Table No.19.

Daily Temperatures of Set A.

Day	Maximum	Mean	Minimum
1	34	3[illegible].0	26
2	32	28.0	24
3	35	31.5	28
4	32	29.0	26
5	29	27.5	26
6	30	28.0	26
7	34	29.0	24
8	32	28.5	25
9	32	31.0	30
10	32	30.5	29
11	32	30.5	29
12	32	31.0	30
13	30	30.0	30
14	35	32.0	29
15	32	30.5	29
16			
17	28	28.0	28
18	34	30.0	26
19	28	27.0	26
20	28	28.0	28
21	32	30.0	28
22	32	30.0	28
23	30	29.0	28
24	36	34.0	32
25	34	31.0	28
26	50	39.0	28
27	30	29.0	28
28	26	25.0	24
Average Mean		30.0	

Table No. 20.

Moulding of Set B. Cylinders

Number Specimen	Time Moulding Min.	Total Wgt. lbs.	Wgt. Residue lbs.	Net Wgt. lbs.	Temperature Air Deg.C	Temperature Water Deg.C	Per cent Water
B 1	9	16.63	1.18	15.45	17.5	23	10
B 2	8	"	1.29	15.34	"	"	"
B 3	8	"	1.37	15.26	"	"	"
B 4	8	"	1.30	15.33	18	21	"
B 5	8	"	1.31	15.32	"	"	"
B 6	8	"	1.31	15.32	"	"	"
B 7	9	"	1.28	15.35	"	"	"
B 8	8	"	1.15	15.48	17.5	22	"
B 9	7	"	1.42	15.21	"	"	"
B 10	8	"	1.59	15.04	"	"	"
B 11	8	"	1.10	15.53	19.6	21.2	
B 12	8	"	1.06	15.57	"	"	"
B 13	8	"	1.51	15.12	"	"	"
B 14	7	"	1.19	15.44	19	20	"
B 15	8	"	1.60	15.03	"	"	"

Table No. 21.

Daily Temperatures of Set B.

Day	Maximum	Mean	Minimum
1	60	59.5	59
2	60	56.0	52
3	58	55.0	52
4	60	56.5	53
5	60	55.0	50
6	50	55.0	40
7	46	42.5	39
8	54	46.5	39
9			
10	55	51.0	47
11	60	57.0	54
12	52	54.0	56
13	56	52.5	49
14	50	49.0	48
15	50	45.0	40
16	48	47.0	46
17	50	47.0	44
18	46	45.0	44
19	48	43.0	38
20	38	35.0	32

Average Mean = 48.0

Table No. 22.

Moulding of Set C. Cylinders

Number Specimen	Time Moulding Min.	Total Wgt. lbs.	Wgt. Residue lbs.	Net Wgt. lbs.	Temperature Air Deg. C	Temperature Water Deg. C	Per cent water
C 1		16.63	1.72	14.91	29	22	10
C 2		"	2.23	14.40	"	20.5	"
C 3		"	1.84	14.79	"	"	"
C 4		"	1.60	15.03	"	"	"
C 5	9	"	1.52	15.11	"	"	"
C 6	8.5	"	1.82	14.81	"	"	"
C 7	8.5	"	2.12	14.51	"	22	"
C 8	8.5	"	1.81	14.82	"	"	"
C 9	8.5	"	1.87	14.76	"	"	"
C 10	8.5	"	1.66	14.97	"	"	"
C 11	8.5	"	1.17	15.46	"	"	"
C 12	8.5	"	2.35	14.28	"	"	"
C 13	8.75	"	1.91	14.72	"	"	"
C 14	8.75	"	1.74	14.89	"	23	"
C 15			1.44	15.19	30.4	"	"

Table No. 23.

Daily Temperatures of Set C.

Day	Maximum	Mean	Minimum
1	79	73.5	68
2	78	76.0	74
3	75	74.0	73
4	74	73.0	72
5	73	70.5	68
6	74	68.0	62
7	75	74.0	73
8	78	75.5	73
9	87	83.0	79
10	78	76.0	74
11	74	70.0	66
12	74	74.0	74
13	80	75.0	70
14	82	73.5	65
15	78	74.0	70
16	78	73.0	68
17	80	76.0	72
18			
19	74	71.0	69
20	77	73.5	70
21			
22	80	73.5	67
23	71	68.0	65
24	73	68.5	64
25	72	67.0	62
26	72	65.0	58
27	71	66.5	62
28			
Average Mean		72.	

Table No. 24.

7 Day Crushing Tests. Cylinders.

	No. Specimen	Average Diameter	Area sq.in.	Crushing Strength (lbs.)	Strength lbs./sq.in.	Average Strength lbs./sq.in.	Remarks
Set A	A 1	6.0	28.25	29240	1034		Cracked
	A 4	6.187	29.95	27670	926		uniformly
	A 7	6.063	28.70	24890	868	893	around cir-
	A 10	6.063	28.70	22450	782		cumferen-
	A 13	6.063	28.70	24450	853		tial area.
Set B	B 1	6.125	29.25	36130	1235		Cracked uni.
	B 4	6.00	28.25	34770	1230		"
	B 7	6.00	28.25	31660	1120	1101	"
	B 10	5.875	27.10	25030	925		Skewed.
	B 13	5.875	27.10	26950	995		"
Set C	C 1	5.875	27.10	27080	997		Visible
	C 4	5.813	26.50	35830	1350		voids.
	C 7	5.940	27.60	37660	1365	1200	
	C 10	5.875	27.10	31140	1150		
	C 13	6.000	28.25	32250	1140		

Specimens were six-inch cylinders.

Table No.25.

14 Day Crushing Tests.

No. Specimen	Average Diameter	Area sq.in.	Crushing Strength (lbs.)	Strength lbs./sq.in.	Average Strength lbs./sq.in.	Remarks
Set A 2	6.0	28.25	38020	1340		Cracked uni-
A 6	6.125	29.25	33340	1140		formly a-
A 8	6.0	28.25	39220	1387	1192	round cir-
A 11	6.0	28.25	31390	1110		cumferential
A 14	5.875	27.10	26700	985		area.
Set B 2	6.00	28.25	47090	1665		Cracked uni.
B 5	5.940	27.60	50460	1825		"
B 8	5.970	27.90	45850	1642	1544	"
B 11	5.940	27.60	30000	1090		Badly skewed
B 14	5.875	27.10	40640	1500		Slightly "
Set C 2	5.875	27.10	46170	1700		Uniform
C 5	6.00	28.25	50000	1770		throughout.
C 8	6.125	29.25	44190	1510	1658	
C 11	6.00	28.25	44420	1570		
C 14	5.875	27.10	47100	1740		

Specimens were six-inch cylinders.

Table No. 26.

28 Day Crushing Tests.

No. Specimen	Average Diameter	Area sq.in.	Crushing Strength (lbs.)	Strength lbs./sq.in.	Average Strength lbs/sq.in.	Remarks
Set A 3	6.063	28.70	39340	1370		
A 5	6.063	28.70	37730	1315		All uniform.
A 9	5.940	27.60	48450	1750	1429	
A 12	6.125	29.25	37660	1285		
A 15	6.000	28.25	40300	1425		
Set B 3	6.063	28.70	56240	1960		
B 6	6.00	28.25	55000	1947		Area reduced
B 9	6.063	28.70	54600	1905	1937	by visible
B 12	6.00	28.25	34670	1230*		voids.
B 15	6.00	28.25	40000	1415*		
Set C 3	5.97	27.90	55720	2000		
C 6	5.94	27.60	63650	2310		
C 9	5.875	27.10	60260	2225	2093	
C 12	5.875	27.10	49760	1835		Slightly skew.
C 15	6.00	28.25	40390	1430*		Badly skewed.

*Not used in calculating average strength.

Specimens were six-inch cylinders.

Table No. 27.

Daily Temperatures Set D.

Degrees Fahrenheit

Day	Maximum	Mean	Minimum
1	64	63.0	62
2	78	69.0	60
3	80	74.0	68
4	78	77.0	76
5	74	73.0	72
6	78	76.0	74
7	81	72.5	64
8	81	72.0	63
9	70	65.5	61
10	78	72.5	67
11	80	76.5	73
12	76	73.0	70
13	76	70.5	65
14	68	65.0	62
15	70	67.0	64
16	69	64.5	60
17	70	66.5	63
18	70	66.0	62
19	66	65.0	64
20	67	63.5	60
21	68	64.5	61
22	69	64.0	59
23	70	66.0	62
24	67	66.0	65
25	65	64.5	64
26	65	62.0	59
27	66	62.0	58
28	64	62.0	60
Average Mean		68.0	

Table No. 28.

Molding of Set D.

Number Specimen	Time Molding (min.)	Total Weight (lbs.)	Weight Residue (lbs.)	Net Weight (lbs.)	Temperatures Air (Deg.C)	Temperatures Water (Deg.C)	Per Cent Water
1	7.0	20.35	1.48	18.87	25.6	21.0	10
2	"	"	1.12	19.23	"	"	"
3	"	"	1.18	19.17	"	"	"
4	"	"	1.23	19.12	25.4	21.4	"
5	"	"	1.14	19.21	"	"	"
6	"	"	0.95	19.40	"	"	"
7	"	"	1.07	19.28	"	"	"
8	"	"	0.82	19.53	"	21.0	"
9	"	"	1.23	19.12	"	"	"
10	"	"	0.82	19.53	"	"	"
11	"	"	1.23	19.62	25.0	21.5	"
12	"	"	0.82	19.53	"	"	"
13	"	"	0.79	19.56	"	"	"
14	"	"	0.82	19.53	"	"	"
15	"	"	0.84	19.51	"	"	"

Specimens were 6-inch Cubes.

Table No. 29.

Molding of Set E.

Number Specimen	Time Molding (min.)	Total Weight (lbs.)	Weight Residue (lbs.)	Net Weight (lbs.)	Temperatures Air (Deg.C)	Temperatures Water (Deg.C)	Per cent Water
1	9.0	20.35	1.08	19.27	24.0	21.0	10.0
2	9.0	"	1.19	19.16	"	"	"
3	8.0	21.10	2.00	19.10	"	"	12.0
4	7.5	21.00	1.10	19.90	"	"	11.0
5	7.0	"	1.36	19.64	"	"	"
6	7.0	"	1.29	19.71	"	"	"
7	7.0	20.35	1.01	19.34	"	22.0	10.0
8	7.5	21.00	1.39	19.61	"	"	11.0
9	7.0	"	1.19	19.81	"	"	"
10	7.0	"	0.95	20.05	"	"	"
11	7.0	"	0.97	20.03	"	"	"
12	7.0	"	0.96	20.04	"	"	"
13	7.0	"	1.36	19.64	"	"	"
14	7.0	"	1.47	19.53	"	"	"
15	7.0	"	1.34	19.66	24.5	21.0	"
16	7.0	"	1.25	19.75	"	"	"
17	7.0	"	1.00	20.00	"	"	"
18	7.0	"	0.90	20.10	"	"	"

Specimens were 6-inch Cubes.

Table No.30.

Daily Temperatures Set E.

Degrees Fahrenheit.

Day	Maximum	Mean	Minimum
1	36	36.0	36
2			
3	38	36.5	35
4	38	35.0	32
5	37	34.5	32
6	35	33.5	32
7	35	32.5	30
8	37	34.0	31
9	39	37.5	36
10	37	36.0	35
11	36	34.0	32
12	36	34.5	33
13	39	37.0	35
14	36	35.0	34
15	37	36.0	35
16	39	38.0	37
17	37	36.0	35
18	35	34.0	33
19	37	35.5	34
20	38	36.0	34
21	38	36.5	35
22	38	36.5	35
23	38	37.0	36
24	36	35.5	35
25	36	35.0	34
26	36	35.5	35
27	38	37.5	37
28	37	35.5	34
29	36	35.0	34
30	37	35.5	34
31	36	35.0	34
32	35	33.5	32
33	36	34.0	32
34	37	36.5	36
35	37	36.5	36
36	38	36.5	35
37	39	38.0	37
38	37	36.5	36
39	35	34.5	34
40	37	36.0	35
41	38	36.5	35
42	38	36.0	34
43	35	34.0	35
44	36	35.5	35
45	35	34.5	34
Average Mean =		35.5	

Table No. 31.

Molding of Set F.

Number Specimen	Time Molding (min.)	Total Weight (lbs.)	Weight Residue (lbs.)	Net Weight (lbs.)	Temperatures Air (Deg.C)	Temperatures Water (Deg.C)	Per cent Water
1	7.0	20.35	0.45	19.90	27.4	20.0	10
2	"	"	0.40	19.95	"	"	"
3	"	"	0.60	19.75	"	"	"
4	"	"	0.66	19.69	"	"	"
5	"	"	0.44	19.91	"	20.6	"
6	"	"	0.57	19.78	"	"	"
7	"	"	0.92	19.43	27.6	20.8	"
8	"	"	0.54	19.81	"	"	"
9	"	"	0.79	19.56	"	19.8	"
10	"	"	0.90	19.46	"	"	"
11	"	"	1.03	19.32	"	"	"
12	"	"	0.92	19.43	"	"	"
13	"	"	0.97	19.38	26.2	20.4	"
14	"	"	0.99	19.36	"	"	"
15	"	"	1.01	19.34	27.0	20.6	"
16	"	"	0.66	19.69	"	"	"
17	"	"	1.08	19.27	"	"	"
18	"	"	1.06	19.29	26.0	20.8	"

Specimens were 6-inch Cubes.

Table No. 32.

Daily Temperatures Pet F.

Degrees Fahrenheit.

Day	Maximum	Mean	Minimum
1	31	31.0	31
2	36	30.5	25
3	28	25.0	22
4	34	31.0	28
5	34	30.5	27
6	34	29.0	24
7	34	30.0	26
8	30	26.0	22
9	30	26.0	22
10	30	26.0	22
11	34	29.0	24
12	36	30.0	24
13	42	34.5	27
14	36	33.0	30
15	42	32.0	22
16	42	32.0	22
17	24	23.0	22
18	24	23.0	22
19	24	21.0	18
20	24	22.0	20
21	28	25.0	22
22	28	23.5	19
23	28	23.5	19
24	28	23.5	19
25	28	25.0	22
26	29	23.5	18
27	28	25.0	22
28	30	30.0	30
29	30	30.0	30
30	30	29.0	28
31	30	29.0	28
32	32	32.0	32
33	32	31.0	30
34	34	29.0	24
35	32	31.0	30
36	32	31.0	30
37	32	31.0	30
38	32	28.0	24
39	24	23.0	22
40	22	21.0	20
41	22	21.0	20
42	21	19.5	18
43	20	19.5	19
Average Mean =		27.1	

Table No. 33.

4 Day Crushing Tests. - 6" Cubes

Number	Weight (lbs.)	Size (in)	Area sq.in.	Crushing Strength (lbs.)	Strength (lbs./ sq. in.)	Average Strength lbs./sq.in.	Remarks
Sat D. D_1	18.50	6x6x6	36	28400	790		
D_2	18.50	"	"	22450	623	777	
D_3	18.50	"	"	33040	920		
Sat E. E_1	19.00	"	"	16690	465		
E_2	19.00	"	"	10000	278	445	
E_3	18.75	"	"	21300	592		
Sat F F_1	18.75	"	"	15680	435		Slight coating
F_2	18.75	"	"	13050	363	386	of frost but
F_3	18.75	"	"	13000	361		all had uniform break.

Table No. 34.

7 Day Crushing Tests. 6" Cubes.

Number	Weight (lbs.)	Size (in.)	Area sq.in.	Crushing Strength (lbs.)	Strength (lbs./ sq. in.)	Average Strength lbs./sq.in.	Remarks
Sat D. D_4	18.75	6x6x6	36	39390	1095		
D_5	19.00	"	"	35930	1000	985	
D_6	18.75	"	"	31000	861		
Sat E E_4		"	"	17100	475		Broke uniformly.
E_5		"	"	19820	551	472	"
E_6		"	"	14060	390		
Sat F F_4	18.50	"	"	20880	580		
F_5	18.75	"	"	19230	534	563	
F_6	18.75	"	"	20760	576		

Table No. 35.

11 Day Crushing Tests.

6" Cubes.

	Number	Weight (lbs.)	Size (in.)	Area sq.in.	Crushing Strength (lbs.)	Strength (lbs./ sq. in.)	Average Strength lbs/sq.in.	Remarks
Set D.	D_7	18.75	6x6x6	36	43420	1205		
	D_8	18.75	"	"	52440	1455	1322	
	D_9	18.75	"	"	47000	1305		
Set E	E_7	19.00	"	"	42310	1175		
	E_8	19.00	"	"	31060	863	920	
	E_9	18.75	"	"	26000	723		Visible voids Broke at one corner.
Set F	F_7	18.75	"	"	15080	418		
	F_8	18.75	"	"	17760	494	505	
	F_9	18.75	"	"	21820	605		

Table No. 36.

14 Day Crushing Tests.

6" Cubes.

	Number	Weight (lbs.)	Size (in.)	Area sq.in.	Crushing Strength (lbs.)	Strength (lbs./ sq. in.)	Average Strength lbs/sq.in.	Remarks
Set D.	D_{10}	19.00	6x6x6	36	58710	1630		
	D_{11}	19.00	"	"	62810	1740	1545	
	D_{12}	18.75	"	"	45530	1265		
Set E	E_{10}		"	"	38630	1070		
	E_{11}		"	"	40300	1120	1103	
	E_{12}		"	"	40280	1119		
Set F	F_{10}	18.75	"	"	19330	537		
	F_{11}	18.75	"	"	26350	732	638	
	F_{12}	18.75	"	"	22900	646		

Table No. 37.

28 Day Crushing Test.

6" Cubes.

Number	Weight (lbs.)	Size (in.)	Area sq.in.	Crushing Strength (lbs.)	Strength (lbs./ sq.in.)	Average Strength lbs/sq.in.	Remarks
Set D. D_{13}	19.00	6x6x6	36	64000	1775		
D_{14}	19.00	"	"	67460	1870	1848	
D_{15}	19.00	"	"	68440	1900		
Set E E_{13}	18.75	"	"	52590	1462		
E_{14}	18.75	"	"	58270	1618	1548	
E_{15}	18.75	"	"	56350	1564		
Set F F_{13}	19.00	"	"	16540	459		
F_{14}	19.00	"	"	15160	421	440	
F_{15}	18.75	"	"	10400	289		

Table No. 38.

44 Day Crushing Test.

6" Cubes.

Number	Weight (lbs.)	Size (in.)	Area sq.in.	Crushing Strength (lbs.)	Strength (lbs./ sq.in.)	Average Strength lbs/sq.in.	Remarks
Set E. E_{16}	18.75	6x6x6	36	66710	1850		Broke uniform.
E_{17}	18.75	"	"	62880	1745	1778	1 corner broke.
E_{18}	18.75	"	"	62240	1738		Slight. skewed